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GAS ENGINE TROUBLES AND REMEDIES

BY

ALBERT STRITMATTER.

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PREFACE.

The gas engine is being rapidly adopted in increasing numbers for all uses for which the steam engine was once regarded as the only practical and profitable prime mover, but the amount of information possessed by the general public on the subject of gas engines is surprisingly small. And as the gas engine does not usually become a menace to life and property when unintelligently handled, it is often the case that the operator does not feel the necessity of having a full understanding of his engine. And even if he is ambitious to secure such knowledge, where is he to get it? There is on the market a considerable number of books which are devoted to the subject of gas engines. Some of these are mainly explanations of various makes of engines, no one engine receiving very much attention. Others of the books are devoted to the methods of constructing gas engines. None of them devote more than a few chapters to the care of the engine or the difficulties which may be encountered in its operation.

This book has been prepared to meet just such a purpose. It has not been intended to be a guide in the design of an engine, nor has it been desired or found possible to give intricate explanations of any particular makes of engines. It has been intended to help the gas engine operator to help himself, to aid him in learning why the engine does not give proper results under certain conditions. In short, it has been the aim to assist him in studying his engine and to gain an intelligent knowledge of it, which will permit him to secure the best results with a minimum amount of care and attention.

Most of the material in the book appeared in a series of articles published in The Gas Engine, but it has been gone over carefully and some changes made, as well as a number of illustrations added.

ALBERT STRITMATTER.

Columbus, Ohio.

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I.

GASOLINE FEED SUPPLY.

In an article published in one of the magazines on the subject of machine tools, it is explained that the hand of man can not make two things exactly alike, but man can make lathes, milling machines, planers, etc., which can work at high rates of speed on the hardest materials, producing the most difficult and intricate shapes with such accuracy that any one piece of a certain type of machine will fit exactly into a definite position on any one or all of thousands of those machines. It has only been since the advance which the United States has made in the interchangeability of parts that we have become the leading machinery country of the world. The delicate machines of all kinds which we now produce are possible, especially at the comparatively low prices at which they are sold as compared with their cost when made by hand labor alone, only by the machines which produce large numbers of parts exactly alike, and to a certain extent, automatically. In some cases these parts do not vary from each other by a thousandth of an inch. Such is the case in the bore of our large coast defense guns, and many of these vary much less than the amount given.

But of all the machines which have been advanced by the progress in machine tools, perhaps none has advanced more rapidly or been due more entirely to such tools than the modern gas engine. For a great many years these machines have been covered with very delicate and intricate mechanisms for operating the governor, valves, etc. It used to be necessary to use these intricate parts in order to get the machines to run at all. And, indeed, it is surprising that many of them ran even then. Many of our gas engines which are made today are perplexing to even the well informed gas engine operator on account of the multiplicity of their parts.

In looking over some of the old types and even some of the more intricate of the modern machines, one is impressed with the fact that only with very good machine tools could such machines be made to operate successfully.

But in the last few years quite an advance has been made toward the simplification of gas and gasoline engines. Manufacturers are continually striving to find out how to drop this or that lever or spring, how to get along without that gear, how to make that curved piece straight and this at a less expense, etc. Why is this? There are two reasons. One, of course, is to reduce the cost of the machine, for, other things being equal, the cheapest machine is the one that sells most readily. But there is another reason which is as important, if not more so, than the element of cost of manufacture. It is that the simpler the engine is, the more easily is it understood and operated and the less trouble does it give. When a purchaser has paid for his engine he sometimes thinks that the manufacturer has no more interest in its successful operation. This is not so, for every manufacturer who expects to stay in business depends on his machines as the best possible source of advertising. One concern I know of sends to each of its customers after having the engine for several months, a letter asking what success the user is having and asking as a favor if at any time difficulties are encountered that they be informed of the nature of them, so that immediate steps can be taken to remedy the trouble. The manufacturer, then, knows that the less trouble his machines give, the more successful they will be and the sales and profits for his concern will be greater. Much has already been done to eradicate troubles with gas and gasoline engines, but much remains to be done. While in some sections they are regarded almost unanimously as the ideal power of the future, in other sections of the country they are regarded as absolute failures owing to *one* or *two* failures in that locality. And as bad news travels faster and is exaggerated more than good news, the failures are more broadly known than the successes.

It may be profitable, therefore, to study some of the causes of trouble with these machines which are admitted by all users to give efficient power at a low cost when they do run successfully. Troubles which have been encountered by others may teach us many a lesson and are perhaps more easily recalled in moments of trouble than abstract accounts. That is the reason why the parable has always been a successful method of teaching.

In the first place, no one should undertake to operate a gas or gasoline engine without studying it and giving it attention. When it has just been received from the factory it is presumably in successful working order, as all manufacturers run their engines on the testing block before shipping. It will, therefore, be of inestimable value to the operator of an engine with which he is unfamiliar to stand by it for hours and study every part and endeavor to learn why each part moves as it does and what would happen if it did not, or if it should wear on the end of the bearing, etc. In this way he learns to know how the parts should operate and as soon as wear occurs, and it will of course occur at some time, he notices the different results and knows how to make slight adjustments.

One of the troubles frequently met with by users of gasoline engines is the difficulty in keeping a proper supply of gasoline up to the engine. In case an engine stops and the difficulty is suspected to be in the gasoline supply, the first thing to do is to see if there is gasoline at the engine feed. These feeds are usually so arranged that this can easily be done. If there is no gasoline there, it may be due to one of several causes, or to a combination of them. First, there may be no gasoline in the supply tank. This may seem a ridiculous difficulty to one who has not encountered it, but there are many cases on record where experts have been sent many miles to locate troubles with gasoline engines when the lack of a supply of fuel was the only difficulty. Quite recently I read an account of a case where a machinist had installed an engine and several weeks later he was summoned to locate the trouble which was being had. He went to the place and the very first thing he did was to inquire if they had purchased any gasoline since he had installed the engine. Then it dawned upon the parties that this had been neglected, and after a fresh supply was furnished to the engine it ran off as merrily as ever. In another case an engine was used in a foundry for running the fans which furnished the blast for the cupola. In the middle of a "heat" the engine stopped and resisted all efforts to make it run. As the iron was fast cooling in the cupola, the only thing to do was to run it out into a large hole in the foundry floor in order to save the cupola. On the following day an expert arrived in response to a telegram and found the only thing wrong was that the supply tank was empty. In this instance the loss occasioned by this neglect was very great, for not only was the time lost, but there was a large amount of iron poured out on to the foundry floor, which it would cost a good deal to break up for use as scrap.

But if there is a supply in the tank, there are other places where the difficulty may be. There may not have been placed at the tank a check valve, and one near the gasoline pump. Dirt or sediment may have gotten into the check valves and thus they may not be seating properly, which would allow the gasoline to flow back to the tank. The suction pipe line may not be tight. When this pipe is put up it should be tested thoroughly to see that there are no air leaks in it, for if bubbles of air work into the pipe they will cause the pump to lose its priming and thus render the supply of fuel irregular. The joints of the pipe should always be put together with soap, not white or red lead which the gasoline eats out rapidly.

Perhaps the pump may need repacking. Several months ago I knew a man to be sent across two large states to locate trouble with a 30-horsepower engine. When he got there he found all that was causing the difficulty was that the packing of the pump needed renewing. When this was attended to, the engine gave no trouble whatever.

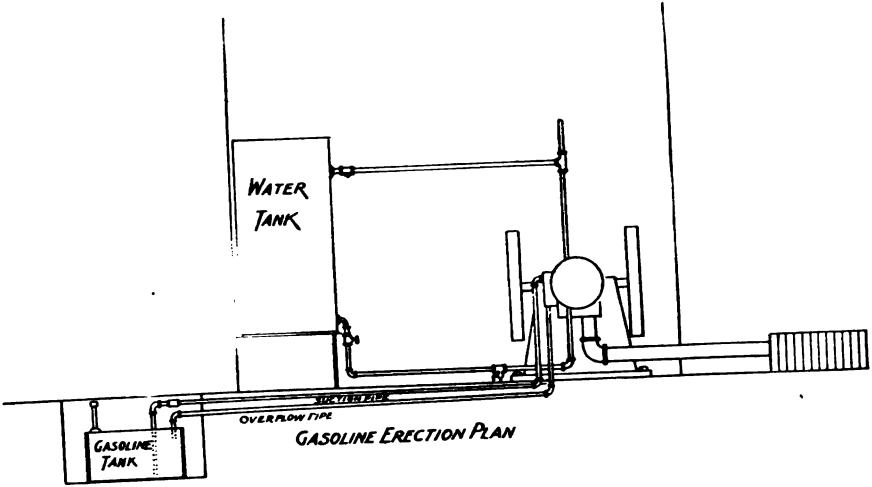
One trouble which is often met in gasoline feeds is that the supply tank is placed too far from the engine, either vertically or horizontally. Gasoline suction pumps will not work under heavy strains because the gasoline tends to vaporize under the suction. Most engines are fitted with pumps which are intended to lift the gasoline not over six feet vertically, and, if to pull that height, not over 15 or 20 feet horizontally. But if the vertical lift is not over two or three feet, the horizontal pull can be made as much as 35 to 50 feet and even farther. The kind of pump and other such circumstances should always be considered. Where it is found necessary to have a vertical or horizontal lift which is too great for the pump, a separate pump must be placed near the tank to act as a force pump.

Sometimes, however, there may be gasoline in the feed box and yet the engine will not get a supply of fuel. This may be due to dirt in the passages of the feed mechanism, or some part of it may be out of adjustment. Some of these feeds are simple, others intricate. In either case they must be studied and understood by the operator so that any trouble which may occur with that particular type can be located and remedied quickly.

Still another cause of trouble is water in the gasoline. This is very hard to detect unless one has had experience with it. A pretty good indication of it, however, is shown by its inclination to "curl" or form globules. If pure gasoline is spattered with the finger from the feed box or some other vessel on to a piece of metal, it will spread out smoothly all over it. If there is water in it, however, there will be little globules run around the same as mercury does when spattered on to anything. Take some pure gasoline and try it. Then mix some water with it and try again, and you will see the difference. Water in gasoline is fatal to the operation of an engine and every precaution must be taken to avoid it. Not that any serious results with it will occur, other than that the engine will stop, but it is a continual source of annoyance and loss of time.

Often the check valves are taken out for some purpose or other and when put back are put in backwards, so that, of course, they will not allow gasoline to be pumped to the engine cylinder.

Ordinarily it is best not to attempt to "fix" something which seems to be wrong unless you know what you are doing or have consulted the manufacturer about it.



GASOLINE ERECTION PLAN

One user of an engine complained that his engine used too much gasoline, about three and a half times as much as the manufacturers claimed was necessary. The makers of the engine even went so far as to test an engine of that same size and see how much gasoline they could push through it and allow the engine to pull its load. They found that the very largest quantity that they could force through the engine was not quite three times as much as was necessary. They therefore seriously doubted the user's statements that the least he could use was three and a half times what they recommended. In many cases the difficulty is really a leaky gasoline tank, so that the engine is blamed for using a large amount of gasoline that never reaches it. In this case, however, the cause was a different one. The manufacturers finally sent a man and found that the people had increased the length of the hollow plug which regulated the amount of fuel it was possible to use. The expert cut off the extra half inch which had been added, screwed the plug down, made a test of the consumption and showed that the engine used only a proper amount.

Another thing necessary to proper and regular fuel supply, as well as for safety, is that the overflow from the engine to the tank be plenty large enough. The pipe should pitch toward the tank, and at no point should it be higher than any other point between that and the engine. If this is not done, there will be danger of flooding the engine and causing high fuel consumption with accordingly decreased power. Furthermore, there will be danger of explosions of gasoline outside of the engine and resulting fires. If the gasoline apparatus is properly installed there will be no danger whatever from fire. The overflow pipe should have a check valve in it near the tank, so placed that in filling the tank the gasoline can not possibly back up into the engine.

The question of the gasoline feed supply can not be too carefully understood and attended to. On the proper installation and adjustment of the various parts depends to a very large extent the amount of the fuel consumption, and as the fuel bill has to be paid right along, it is well to reduce it as low as it possibly can be done.

In later chapters will be considered the effect of too much or too little fuel on the power developed and as related to other parts of the engine.

II.

STARTING.

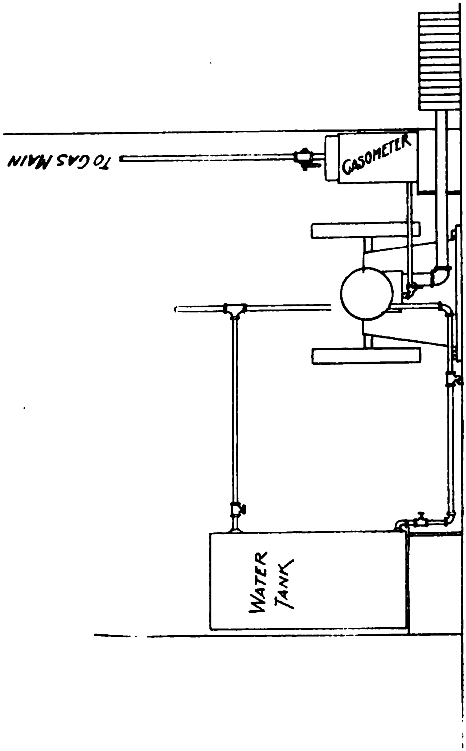
In the previous chapter attention was called to the necessity of the gasoline engine operator thoroughly understanding the installation and operation of the gasoline supply, such understanding being essential to the successful operation of his engine. This is necessary, not only in order to keep the engine running properly while it is in proper condition, but also in order that he may locate any troubles which may arise in the future. Gasoline engines, like watches, are largely automatic, but there is no machine made which does not need some attention and which will not require intelligent attention when troubles arise from wear, etc. No one would think of putting his watch in the hands of any one but a watchmaker for repairs. A gasoline engine, likewise, should not be entrusted to the care of one who knows nothing about it, or at least is not willing to study it while it is in good running order, that he may know what to do when difficulties arise.

Manufacturers of gas and gasoline engines frequently receive letters from their customers stating that they have tried in vain for several hours to start their engines with nothing apparently wrong, that sometimes the engine starts on the first attempt, and at other times refuses to do so for hours, and then, without anything having been done to it, it starts off all of a sudden. Many operators are almost willing to swear that some stubborn ghost or evil spirit has taken hold of the engine. And yet the solution of this question is a simple one.

Everyone knows that for gas or gasoline to burn, oxygen or air must be present. We also know that if we have a small amount of gas or gasoline vapor mixed with a very large amount of air, it will not burn. On the contrary, if we have a large amount of gas or gasoline in an air-tight compartment and then inject a very small quantity of air, this mixture also will not burn. In other words, there must be a certain proportion of air to gas or gasoline in order to permit of combustion. Experiments show that while gas or gasoline will burn when mixed with varying quantities of air within certain ranges, there is for each gas a certain proportion of air which gives the greatest explosive effect or the greatest pressure. This proportion varies according to the number of heat units of the gas or gasoline vapor, also with the pressure of the air.

Suppose that we attempt to start an engine and use a certain priming charge which happens to give a proper mixture in the cylinder. The engine starts off at once. Perhaps the next time we try to start the engine we do not use as much gasoline for the priming charge, and it fails to ignite, and the engine does not start. Or, on the other hand, we may use too large a charge and the engine fails to start because the mixture is too rich to ignite. It is necessary, therefore, to learn by experience about what sized priming charge to use. One mistake commonly made is, if an engine fails to start on the first attempt, immediately to put in another charge and try again. As the first charge is still in the cylinder the addition of a second or following charges simply floods the cylinder, making it impossible for the charges to ignite. When the first charge does not explode, always open the valves or relief cocks and turn the engine over idle to blow out the charge. Then start over again. The failure to do this accounts for many of the vain attempts to start an engine, lasting several hours.

But perhaps some day we shut the engine down for a few minutes for some cause or other and when we try to start again can not do so. I recently learned of a case where a prospective buyer of an engine went to see a certain make. He made inquiries of the owner as to whether or not it was easy to start it. "Oh, yes," said the owner, "it doesn't take a minute. I'll shut her down and show you how easy it is. I never miss starting the first time." But, alas, when he tried to start it he couldn't do it for the life of him! A fine



Gas Erection Plan

recommendation for the engine. And it was all due to the fact that the operator failed to understand the questions which we have just been considering.

In the morning when he started the engine he used a certain sized priming charge. When this was drawn into the cylinder the cool walls condensed a portion of it, but enough was left in suspense with the air in the cylinder to make an explosive mixture and to ignite from the spark. When he shut down his engine and attempted to start, however, the cylinder was very hot. He used the usual size priming charge, but as the walls of the cylinder were hot, none of the charge was condensed and all was vaporized, making the mixture too rich to explode. If he had used about half the usual sized charge there would have been no difficulty.

There is also a contrary condition. Suppose that this same man attempted to start up some very cold morning and used the same sized charge that he had been accustomed to in moderate weather. The cylinder being exceedingly cold would condense practically all of the charge, and there would be too little left in suspense with the air to ignite. Many a man has, under such conditions, telegraphed to the factory to send a man, as he could not start the engine. It would have been cheaper and saved much time if he had simply used about double the usual quantity of gasoline for his priming charge.

I imagine some of my readers are saying: "Well, why in the world doesn't the manufacturer tell us this in his instruction book?" Are you quite sure that he doesn't? I have not seen the instruction books of all manufacturers of gas engines, but I have known of some gas engine operators who had the very difficulties against which their instruction books cautioned them specifically. Possibly they had read the books when first received, and had laid them aside, never looking at them again. You can not afford not to read your instructions over and over. It is never too late to learn something about the engine, and you can not expect to absorb all there is in the book on the first reading or two, especially if you are not familiar with this particular make of engine. Besides this, it will save you much time and money some day when trouble comes and you are too busy or "rattled" to spend much time hunting in your instruction book (if you can find it) for a possible remedy.

One of the loudly proclaimed virtues of a gas and gasoline engine is that it is easy to start at a moment's notice. It can be started without waiting to get up steam, and can be stopped at any time for a few minutes or for hours, the expense stopping at once, and it can then be started again when needed. This is indeed a valuable feature in any internal combustion engine and yet it is not too much to say that there are great numbers of them which do not actually possess this desirable feature. Why? In many cases it is due to improper construction of the engine. But where the engine is all right it is invariably due to the lack of an understanding on the part of the operator as to what actually happens in the process of starting an engine. Many an operator goes through the process of starting his engine just as a parrot does his set phrases. If you ask the parrot a question he can not answer it except as he may squawk off some set phrase which he hits upon by chance. Many a gas engine operator on being asked why he does this or that to start the engine, simply answers: "Oh, that 's what you have to do. I don't know why, but you have to, that's all."

He is like a firm who were having trouble with an engine which they had purchased through a local man who knew no more about it than they did themselves, but who had made them believe he knew it all. The manufacturer wrote to them, asking how the engine worked, wherein it seemed not to be doing as it should, and so on. The reply which came back was significant and typical of many a gas engine operator:

"As to the engine, we know nothing about it. We leave that all to Mr. Richards, of whom we got it. We never do anything to it except to fill up the oil cups."

These people had as specific instructions as it is possible to put in the form of printed matter. They did not even have the curiosity to learn whether the engine was giving trouble because of failure to compress, ignite or what. All they knew was that it did not do the work, and all they did about it was "to fill up the oil cups." They are, as before stated, typical of many gas engine operators.

But the matter of proportion of gas or gasoline to air affects the consumption of fuel and the power developed by an engine, as well as the starting of it. This is a very important matter and will be considered in the next chapter.

III.

FUEL CONSUMPTION.

Why is it that one man with a certain size of standard make of engine is well pleased with the power it develops and the low fuel consumption, while another man with the same make and size of engine declares that the engine does not develop the power at which it was sold, and that it uses much more fuel than it was represented to him would be used? The engines are the same size and make, yet one may be developing half the power of the other, but with twice as great a fuel consumption. The power developed and the fuel consumption may, at first thought, appear to be only distantly connected, or if connected at all the connection may be expressed by "more fuel, more power." Right here is one of the stumbling blocks of the inexperienced operator of a gas engine.

What more natural thing in the world than to give the engine a little more fuel when you see the load is too heavy for the engine and it is beginning to slow down?

But let us consider for a few moments how a gas engine operates. In the previous chapter attention was called to the fact that the gas or gasoline and air must be mixed in certain proportions in order to ignite at all, and in one certain or definite proportion to give the greatest possible power or explosive pressure. Roughly speaking, about one volume of gas to seven of air is found to give the best results, although this depends on the quality of the gas. For economical fuel consumption, then, we must have this mixture at each explosion.

At this point enters the question of throttling and hit-and-miss engines. With the latter type the mixture of fuel always remains the same, and when the engine gets above speed one or more charges are "cut out" until the speed drops to or below the normal, when another charge is taken. In this way the greatest possible pressure is secured from each charge, which is taken in. With the throttling engine there are two types. In both, the intention is to take an impulse at every opportunity, i. e., on every revolution or every other one according as it is a two or four-cycle engine. If the speed gets above the normal the charge is decreased in size so as not to give as strong an impulse to the piston. In one type, however, the mixture remains the same, that is, the proportion of air and gas is the same, the size of the charge being diminished. However, as the charge is decreased, the compression is less, and therefore the explosive pressure is not so high. With the other type of throttling or graduated charge engine the amount of air for a charge remains the same, but the amount of gas or gasoline is graduated. This, as will be seen, at once destroys the ratio of the mixture at which the greatest force is derived, and therefore causes increased fuel consumption, because the maximum possible power is not secured from the fuel used. Further than this, if the speed gets too high, the amount of gas or gasoline admitted to the cylinder is made very small. When the ratio of gas to air gets beyond a certain limit, say

1 of gas to 15 of air, the charge fails to explode, and the fuel is therefore exhausted, unignited, and is wasted. To remedy this waste, the manufacturer of such an engine resorts to cutting out the charge after reaching a certain limit, but in so doing he adopts the hit-and-miss principle, which he otherwise condemns.

Taking a hit-and-miss engine, however, and having a proper mixture to give the greatest power, suppose the engine stalls and we want more power. If we give it a large-sized charge we at once destroy the ratio that gives the greatest force, and we therefore get less instead of more power from the charge. If, on the other hand, we decrease the amount of fuel, we likewise decrease the proper ratio and also get less power. Getting less power from each charge, it is necessary for the engine to take more frequent charges in order to maintain the speed. We therefore have the unlooked for, but perfectly natural, result of using more fuel and getting less power.

Suppose we have a throttling engine of the type which keeps the ratio of gas or gasoline to air the same and regulates the speed by decreasing the size of the charge, or increasing it. Suppose the engine is so adjusted that the most advantageous ratio is not secured. At once the power from each charge is decreased, and more of the large-sized charges will, therefore, be taken, resulting in increased fuel consumption to maintain the load and speed.

It will thus be seen that no matter what kind of an engine we have, there is a possibility of getting the charges too rich, and in the hit-and-miss type of getting them too weak, either of which means a higher consumption of fuel for a given load and speed than would be necessary if the proper adjustments were made.

Granting this, how are we to know when we have secured the adjustment which gives the best results? By watching the results is the best way. The perfect mixture will give perfect combustion. Perfect combustion gives a clear exhaust. Whenever a gas or gasoline engine gives a smoky exhaust it is due to one of two things. First, too much fuel may have been supplied the engine, resulting in imperfect combustion. Second, too much lubricating oil may have been fed, the surplus not used in lubricating the cylinder being burned and making a smoky exhaust, as well as clogging and gumming up the piston rings, exhaust ports, exhaust valve, stem, and so on. If you have a smoky exhaust, therefore, look first at your lubricator and if, after cutting down the supply of oil, the smoke does not stop, look at your fuel valve. If the condition is due to too much lubricating oil and has existed for some time, it may take several days to overcome the smoking, as the oil, which has been deposited in the exhaust passages, may be several days getting burned out.

Another way to tell whether you are using too much fuel is to note your fuel bills for each month and compare them with each other. Of course, in a place where the load is quite variable, this cannot be done successfully. But even then you can generally tell whether your load for one month has been very much more or less than the previous month. Bear this in mind and determine in the best way you can about how one month compares with another, and then compare the fuel bills. If one bill is very much larger than another and the load has been approximately the same, probably there has been some waste of fuel.

There is one very good way in which to secure fuel economy if you are hiring a man to take care of your engine and if your load is approximately the same right along. Suppose your fuel bill has been running about $20 per month. If, by any means, you could get it down to $10 per month or less, would it not be worth while for you to pay your engineer a few dollars more per month? Tell him that if he can get the cost of fuel per month under $20 you will give him half what he saves. It will surprise you what the result will be. He will study the engine as he never did before. He will see where this piece is out of adjustment, or that piece is worn out, or the battery is weak and fails to ignite every charge, and so on. He will keep the engine clean and in nice shape, knowing that everything counts in lowering the consumption, and that of every dollar saved half will be his.

It must not be understood, however, that high fuel consumption is due entirely to improper regulation of the fuel valve. If the engine fails to ignite a charge because of weakness of the battery or failure of the igniter to work at the proper instant, the charge is exhausted unexploded. This of course increases the consumption because more charges are taken and some of them are not exploded in the cylinder. These unignited charges which are exhausted remain in the exhaust pipe, and as soon as the next charge, which is ignited, is exhausted, the hot flame ignites the charge in the pipe, causing an explosion which is often regarded as dangerous by persons near. As the exhaust pipe, however, is always as strong as the engine cylinder, it is ample to contain these pipe explosions, which usually result in nothing but a little scare and increased consumption of fuel.

Furthermore, a bad exhaust system may produce this increase in consumption. If, for any reason, the burned gases can not readily escape from the cylinder there results considerable back pressure with an excessively large amount of these gases remaining in the cylinder. The result is that the incoming charges are so polluted by the burned gases as to destroy their effectiveness. Sometimes this occurs to such an extent that the charges fail to ignite at all. Ordinarily, however, it simply results in less power developed and more fuel used.

High fuel consumption, then, may mean that the igniter is in need of attention, or that the exhaust system is defective, as well as that the fuel valve may be improperly adjusted. Each particular part must be carefully examined, and the defect, wherever it exists, located and remedied.

Referring again to the question of throttling and hit-and-miss engines, which is the better? This is largely a matter of personal opinion, and it is practically impossible to answer the question to the satisfaction of everyone. A great deal depends on the conditions under which the engine is installed. Manufacturers of hit-and-miss engines claim that the consumption of the throttling engine is enormous. Their competitors claim that the variation in speed of a hit-and-miss engine is likewise enormous. Both deny the claims made against their own engines. As a matter of fact, a great many hit-and-miss engines are doing electric light and other work requiring a very close regulation, and are doing it satisfactorily. On the other hand, some gasoline engines of the throttling type have a very satisfactory consumption. It is all the more difficult to decide the matter from the statements of some engine operators, because if one man says his speed is very irregular, or another his consumption is very high, how are we to know whether or not they have their engines in proper adjustment to secure the best results? Might not better results be secured if some one else were in charge of the engines?

Eternal vigilance is the price to be paid for some things besides liberty. It certainly is the price that must be paid by all business men in the period of competition now existing. The power plant is one of the fixed charges which every factory of any size, or any building devoted to office purposes, must endure. It may be regarded as a necessary evil, but it is there and the best thing to do is to make it cost as little as possible. Constant study and effort to reduce the daily cost of operation is one of the ways to reduce the fixed cost of the power plant. We have seen how, with a gas or gasoline engine, we can in some measure accomplish this result.

IV.

IGNITION.

Among the various parts of the gas or gasoline engine, none is more important than the igniter, which is frequently referred to as the soul of the engine. Of all the troubles met with in gas engines, I believe far the greater portion of them is due to the ignition, either directly or indirectly. Much of this has been due in the past to complicated mechanisms which required very fine adjustment, while a great deal has also been due to the lack of a realization on the part of the operator that the fuel consumption, the power developed, and the life and satisfactory service of the engine depended to a very large extent on the proper ignition of the explosive charge.

In considering this subject of ignition, it may be well to recall various methods of ignition in gas and gasoline engines. First may be mentioned the Otto slide valve type, familiar to all old-time gas-engine men. Then there is the hot tube igniter, the electric igniter, and the method of the Diesel motor of raising the temperature under pressure to the point of ignition. As only the hot-tube and electrical methods are in current use, we shall not consider the others.

Comparing the electric and tube igniters, the latter is, of course, the simpler, especially if a gas burner is used. The tubes, which are of different compositions, are simply heated by a Bunsen burner to such a temperature that when the engine compresses its charge the burned gases in the cylinder are first forced up into the tube, and the live charge follows and ignites from contact with the heated surface of the tube. The hot tube method is not quite so convenient as the electrical method, as one must wait a few minutes to heat up the tube before starting. As the atmospheric conditions affect the time of ignition with the hot tube, and as these conditions change from day to day, the exact time of ignition will vary to some extent. Further, as the conditions where engine is installed are probably different from those at the factory, tubes which work all right at the factory may not do so after the engine is installed.

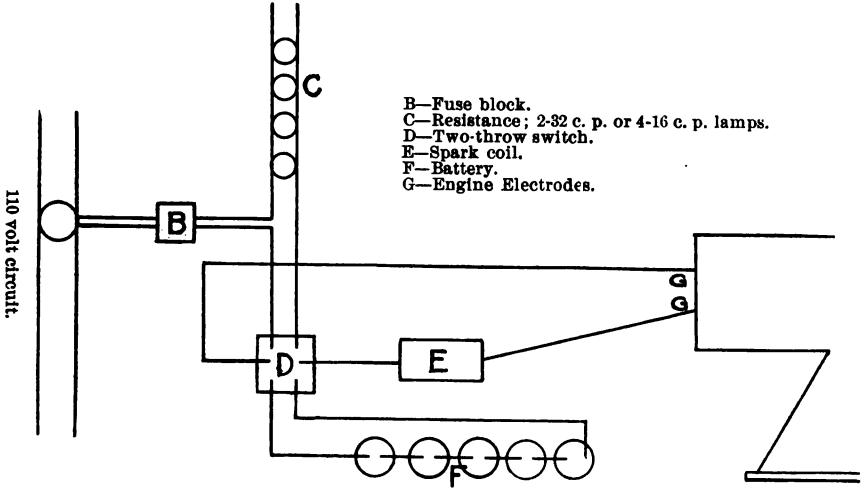
If an iron pipe is used for the tube it soon becomes coated on the inside to such an extent as to delay and even prevent ignition. Anyone who uses a tube igniter continuously, however, should not use the iron tubes, as they burst easily after a little use. Nickel alloy and other special tubes are used to a large extent, and it pays to use only the best.

The greatest difficulty with the tube igniter is its changeable character and the fact that one can not tell at just what point ignition takes place, except by indicating the engine, which few people are prepared to do. In some makes of engines, especially the earlier ones, a valve was placed leading to the tube, and this valve was opened at the proper time to allow ignition. This, however, has been generally discarded, as it merely allowed the gases to reach the tube at a certain time, and did not determine the time of actual ignition. For portable use the hot tube is decidedly a disadvantage, as the wind can play on the burner flame, and the tube is not kept at one temperature, and even where protected from draught the flame may be hotter one day than another, unless the operator is very careful to note the adjustment of his burner.

The electric igniter, while disliked by some, many of whom use it only because they like it better than the tube, is slowly forging to the front as the ideal igniter for a gas engine. Much of the opposition to it has been due to complicated mechanism, to batteries which would not last long, but largely to the unintelligent care of the operator. In the make-and-break igniter two electrodes form a part of the electric circuit. Of these one is usually stationary and insulated from the rest of the engine. The other electrode is movable, and as it is brought into contact with the stationary electrode the electric circuit is completed. Then, at the proper time, the circuit is suddenly broken by separating the points quickly, thus getting a spark from one to the other and igniting the charge. A variation of the make-and-break method is the wipe method, where there is a slight wiping or chafing action of the two points.

Then there is the jump-spark method. By this method a spark is made to jump across the short distance between the two electrodes, being accomplished by the use of an induction or Ruhmkorff coil.

With the make-and-break method it is very necessary that the insulated electrode be perfectly insulated. Various substances are used for this purpose, but all are likely to get injured by articles falling on them, etc., in which case they must be renewed. Sometimes there will be a crack in the insulation, which, when cold, will not show any effect, but as soon as the insulating material gets warmed up it expands, the crack opens, and the insulation is defective. Then the points in the electrodes must make a good contact. Sometimes one or both get loose and they do not meet, or perhaps they will wear down to such an extent that they do not make a contact. Then, too sulphur in the gas may insulate them. Or they may get



B—Fuse block.
C—Resistance; 2-32 c. p. or 4-16 c. p. lamps.
D—Two-throw switch.
E—Spark coil.
F—Battery.
G—Engine Electrodes.

General plan for connecting engine with battery and lighting circuit for electric ignition.

rusty and be partially insulated. Steel, German silver, platinum and other substances are used for these points. One gas engine operator will swear by platinum, while another is positive that platinum is not the ideal point, but that German silver or steel produces the best results. Much depends on the nature of the fuel used, etc. Perhaps the best advice to give on this subject is to try the various substances and note which seems to give the best results in each particular case.

Of course it is necessary that the battery be strong and effective. The proper kind of a battery to use is another much discussed question with gas engine manufacturers and users. One advocates a dry battery of a certain number of cells. Another proclaims the merits of the liquid battery with a different number of cells, and so on. As a matter of fact, no battery is too good, and any battery will give poor results if allowed to short circuit. Too many operators forget to open the switch when shutting down the engine, and the result is that the battery runs down more in one night than it would from several weeks or months of usage. The switch should always be thrown open when engine is not in use.

Then, too, electric bells should not be run with the engine battery. Sometimes the battery is placed on a shelf, and a lot of metal and rubbish is piled on top of it, thereby short-circuiting the battery. In putting renewals in a liquid battery, both the plates and the solutions should be renewed at the same time, as the different elements are generally so proportioned by the manufacturers of batteries as to deteriorate together, thus making complete renewals necessary. Sometimes the operator allows his spark coil to get damp, which destroys its usefulness, as it must be kept dry.

In cold weather the engineer sometimes is afraid that his battery will freeze during the night. One of the largest battery manufacturers in the country states that one type of his battery will easily withstand a temperature of zero degrees, F., while another type which is more commonly used for gas engine service will stand 15 to 20 degrees below zero. He states, however, that it is unwise to get as low as either of these temperatures if avoidable.

There is one point about a battery that a great many people do not understand. One man has a 5-horsepower engine while another has a 60-horsepower, and perhaps the smaller engine requires twice as many battery renewals as the larger one. Why this should be the case is a mystery to some engine users. And yet the reason for it is perfectly plain and natural. An electric battery is often compared to a barrel of water. If you take one drop of water out of the barrel every second continuously for ten hours a day, the water will not last as long as if you took a drop out only every minute for ten hours a day. Similarly, if you draw a spark continuously from your battery every second, the supply of sparks will not last as long as if a spark was taken only once a minute. Now, small engines run at a much higher speed than large ones, and therefore require more sparks per minute. The result is that the faster the speed of the engine is, the shorter will be the life of the battery.

Some engines of the hit-and-miss type do not operate the igniter when a charge is not to be ignited, while other igniters operate continuously, thus making a spark even when not required, and running down the battery unnecessarily. With those hit-and-miss engines which cut out the igniting mechanism when a spark is not required it will be seen that the heavier the load the shorter the life of the battery, because the heavier the load is the more charges are taken and exploded, requiring that many more sparks.

Another rather puzzling thing about batteries is, that under apparently the same care and conditions, one will last much longer than another of the same make. This seems to be especially true of dry batteries. In some cases a battery will give out within three to six months, while the next one may last as long as a couple of years, as is sometimes the case, although very rarely. The only plausible reason for such occurrences, in cases where the battery is well cared for, seems to be that the batteries are not standard, and if one gets a battery which lasts for an unusually long period of service he is to be congratulated.

With the wipe-spark method there is a tendency for the contact points to wear from the continual rubbing, so that it is necessary to watch and see that the electrodes do not wear off too much before adjustment is made. Of course, the chafing action keeps the contact points clean and bright, so that they do not get a chance to corrode and become insulated.

In the jump-spark method the main difficulty, outside of securing a satisfactory coil, is encountered in the fact that the points inside the engine do not come into contact, and are not, therefore, kept clean as easily as even the points in the make-and-break method. This results in rust, carbon, sulphur, etc., depositing on the points, so that it becomes necessary to clean them frequently. The fact that there are no moving parts or springs within the cylinder is its most advantageous characteristic.

It can not be borne in mind too strongly that the igniting mechanism must be absolutely correct in order to secure satisfactory results, both in the power developed and in the amount of fuel consumed. If a battery is used, as before stated, it must be of the best, for, if the igniter is the soul of the gas engine, the battery may properly be called the vital essence of the soul. Even though the exhaust or compression of an engine is poor, yet, if the igniter is all right, some kind of results can be secured. But, on the other hand, if everything else about the engine is absolutely correct, and the igniter fails, no results can be secured. And yet, in spite of this, many gas engine operators do not attempt to study either the principle or the mechanical operation of their igniters, and the result is that they are continually having trouble.

Many an engine which has been condemned as unsatisfactory and a failure has been so only because of the lack of intelligent care of its igniter and a knowledge of what care to give it and when. Many of these very same engines have gone into the hands of other people who have studied them a little and learned what to do, and the results have been just the reverse of what were secured by the first operators, due simply to the application of some intelligent care.

But the fact that the igniter works all right in itself, does not mean that good results will be secured from it. One thing to be borne in mind in considering the operations of a gas engine is the time when the operations take place. Many an engine has a good igniter, and would have been better off if it had had none at all. Why this is so, and the relation of the time of ignition to the successful results to be secured, will be considered in the next chapter.

V.

TIMING.

In the previous chapter we called attention to some of the more common troubles met with in the operation of the gas engine igniter. While the gas engine is not as complicated as a steam plant, including engine, boiler, etc., yet the various parts of the engine bear such a relation to each other that they must act in unison. In other words, the various parts must be in "time" with each other. An engine may have a perfect form of exhaust valve, yet if the valve does not open at the right time in the operation of the engine, it is of little value. This is a point which is sometimes overlooked by gas engine users who may be having some trouble with their engines. They will examine every possible point, yet be unable to find the cause of the trouble, when the whole difficulty may be that some part is out of time. That this matter of time is one which affects the power and the consumption of the engine is recognized by few engineers, and it is important that the subject be carefully understood.

If the intake valve does not open promptly as the engine piston starts forward on the first stroke, it results in too small a charge being drawn in. In some makes of engines, which govern on the fuel supply instead of on the exhaust, the fuel valve, or both the air and fuel valves, are not opened until a portion of the stroke is completed, in order to give a weaker explosion when the engine gets above speed; but even in this type of engine the valves should open promptly at the proper time.

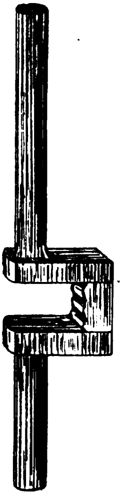
On the other hand, if the air and fuel valves open before the completion of the previous exhaust or sweep-out stroke, a portion of the exhaust is blown out through the air and fuel valves, and of course they close before a proper sized charge is admitted to the engine. This premature opening of the fuel valve often results in "back firing," or ignition of the fuel from the flame of the exhaust, causing a report in the air and fuel passages. And if the fuel valve opens too late, it may be too late in closing, resulting in a portion of the charge being blown back through the valve on the compression stroke.

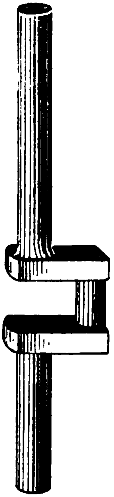
But the time of the ignition is perhaps the most important, if any one thing can be fixed on as the most important, when the proper timing of all the parts is necessary to good results. But improper timing of the ignition has perhaps the most disastrous effect on the engine. The time at which the igniter should operate is when the crank-shaft is just far enough ahead of the inner dead center on the compression stroke, so that the greatest pressure from the combustion of the charge occurs at the dead center or just past it. In many engines used for electric light work, where the main result to be secured is not so much low fuel consumption as it is very close regulation in speed, the ignition is adjusted so as to be a little late, giving a little less jump to the piston at the time of ignition. Thus it will be seen that the ignition really begins a little before the completion of the compression stroke, or before the crank-shaft reaches the inner dead center. This is called the "lead" of the ignition.

Suppose that the igniting mechanism operates at such an instant that the piston will start on the out stroke before the charge is ignited and starts to expand. As the piston moves out the compression at once begins to decrease, and the amount of pressure obtained is therefore less than would be secured if the ignition took place at the proper time. Of course, when regulation is the prime essential and even a very slight variation in speed is undesirable, it is perhaps well to secure this by late ignition, but it must be remembered that late ignition means the same as low compression.

On the other hand, suppose that the igniter operates at such a time that the complete ignition occurs before the crank-shaft reaches the inner dead center. It will be seen at once that the engine must then work against itself. The tendency of this would be to reverse the engine, but the momentum of the flywheels carries the piston on even against the enormous pressure. Of course, the power of the engine is decreased, because the efficiency of the engine is greatly decreased in overcoming the tendency to reverse. But if early ignition continues for any length of time it will eventually partially or totally wreck the engine. As has been explained, at the time of the early ignition the crank-pin is below dead center, and the engine would naturally tend to reverse. This does not occur, from the fact that the momentum of the flywheels carries it on. However there is a very heavy torsional strain on the crank-shaft, since the piston and connecting rod are forcing it in one direction, while the flywheels are forcing it in the opposite. This strain, if kept up for any length of time, starts a small check or crack at the junction of the crank-cheek with the journal. This crack gradually works all around the shaft and into the cheek at an angle of about 45 degrees, or, rather, in a curved line. Finally there is so little stock left that this suddenly breaks and leaves the cheek with a cup-shaped depression, into which the broken end of the shaft fits. As the crack gradually works in farther and farther, the vibration rubs the broken parts smooth and oil follows in. When the final break does occur this oily and smooth surface has the appearance of an old break or a flaw, while the small portion of the fracture which broke last is the only part which shows a fresh, rough break. This frequently creates a wrong impression in the mind of the owner of the engine, who at once jumps to the conclusion that, since the break has undoubtedly been of long duration, and as it shows a smooth surface over the larger portion of the fracture, the shaft must have been welded into the cheek and the weld imperfectly done. Accordingly, he demands of the manufacturers a new shaft free of charge, as well as that the rest of the engine, which may have been damaged more or less, be repaired without cost to him.

As a matter of fact, practically all of the reliable gas engine builders, especially those building engines larger than 5 H. P.,





use a crank-shaft which is forged from one solid billet of steel, and the crank portion is solid. The stock between the crank-cheeks is then cut away and the shafts and crank-pin are turned to the proper size, so that there is no welding in any part of the crank-shaft. These breaks sometimes occur several years after the installation of the engine, long after any defects in the construction of the shaft would have developed. The accompanying illustration shows the rough-turned and the finished crank, also the usual form of break.

But there is another result which accompanies either early or late ignition, or the wrong timing of the valves, and that is high fuel consumption. Early ignition destroys the effect of a large part of the latent power in the charge. Late ignition, like low compression, does not secure all the power possible from each charge, since there is a relation between the maximum pressure secured after ignition and the pressure at time of ignition, so that the lower the pressure at time of exploding, the less is the power developed. Early or late closing of the air and fuel valves also results in losing a part of the power possible to secure. And as all gas engines which do not get the maximum benefit from each charge require more fuel than is otherwise necessary, it will be understood that any of the conditions previously mentioned affect the consumption of fuel per horsepower developed.

But what are some of the causes of early ignition in gas engines, and how is one to tell when ignition occurs at the proper time? Indicating the engine is the only way by which the exact time for the igniting mechanism to operate can be told, but there are ways to tell very closely without indicating the engine. It is often very difficult to tell, except by the use of the indicator, whether an engine which is run with a tube igniter is firing properly or not, unless the time of ignition is exceedingly early or late. If very early the engine will make a pounding noise. If very late the power developed will be very little and by experimenting with various lengths of tubes something may be learned about the time of the ignition.

An engine which has an electric igniter operates the igniting mechanism while the crank is at a certain point below dead center. It is well when the engine is new and in proper condition to make a mark in some way to show the position of the crank at this time. One way to do is to make a mark on the flywheel, and another close to it on some part near the wheel. If this can not be done easily the piston may be marked, or a plumb-line may be dropped from the center of the flywheel shaft and a point marked on the rim of the wheel where the line meets it. Many makers of engines have some special way of marking this on their engines, so as to avoid the necessity of the purchaser doing so. By having some guide when the engine is new, it enables the operator to tell at any time whether the engine is igniting properly.

As to the causes for early or late ignition, first, the engine may be out of adjustment. All igniting mechanisms wear in time and require some readjustment. Sometimes they are changed accidentally by some person taking off a portion of the engine and not putting it back correctly. Often a side shaft is taken off and when put back the gears are not meshed with the same teeth together. A difference of even one tooth will throw the whole engine out of time. Sometimes a deposit of carbon or the head of a screw or bolt, or some sharp corner in the cylinder becomes heated to such a point as to ignite the charge prematurely. In such cases if the battery is disconnected the engine will ignite charges just the same, as long as the heated part continues to be sufficiently hot.

Sometimes in an engine with a make-and-break igniter new points are put in and their length is not gauged properly or adjustments are not made to take care of the different length of points, thus changing the time of ignition. Or the points may wear gradually, and by so doing change the time of ignition. All engines have parts which wear gradually and these points are sometimes not noticed by the owners. Many people who have had a crank-shaft broken from early ignition will tell the manufacturer that the time of ignition has never been changed since they got the engine. They seem to think that since nothing has been done to the engine the time of ignition must be the same as when it was new. As a matter of fact their very statement that they have not adjusted the engine shows that it can not be in the same condition as when shipped, because wear has taken place and changed it. "Letting the engine alone and doing nothing to it" has ruined more than one machine and the efforts of gas engine manufacturers are being continually devoted to trying to educate the purchaser up to the realization of the fact that no engine can be "let alone" with impunity. No one expects a horse to be let alone and yet do satisfactory work. And a good gas engine is in some respects like a good horse. It runs best when cared for best. No part of the engine can be neglected without resulting in trouble.

But the fact that any part of an engine is in proper condition itself does not imply that it is in proper time. One of the mystifying things about a gas engine, at least to the person who is unfamiliar with their operation, is to see some part jump up and down perhaps three or four times and then stop, and pretty soon jump up and down again with apparently no reason for its doing so. Some operators of engines do not have enough judgment, or even enough curiosity, to learn why such a part moves as it does. The gas-engine operator must never lose sight of the fact that gas engines are largely automatic and that there is a reason why each part not only moves as it does, but when it does, and any operator who has the foresight to know that he should understand the action of the engine thoroughly will study these features, and thus will save himself many an hour which would otherwise be consumed in looking for the cause of an engine shutting down or waiting for a new crank-shaft or other parts to come from the factory.

VI.

ILLUSTRATED TROUBLES.

Knowledge of any subject may be divided into theoretical and practical, and in order to have the best acquaintance with any subject, the more of each kind we have the better we are equipped. The truly educated man recognizes this fact, but there are many so-called "practical men" who look upon the "theoretical man" with disgust, and *vice versa.* And yet, if all men belonged to either one or the other of these classes, it would be very difficult for either class to get along without the other. It is necessary, therefore, that the practical man who has learned what he knows from actual experience to acquire as much as he can of the theory of what he practices. It is likewise essential for the man who has learned from books the why and wherefore of this and that to get by experience some additional knowledge which can not be secured in other ways.

I once heard of a young man in a college class who was given the dimensions of a certain gas engine and asked to figure out the size of pipe necessary to supply the engine with gas. The young student in question gave as his result, a 1¼-inch pipe. The professor in charge claimed that 1⅛-inch pipe would be sufficient, but was met by the answer, "Where will you get your 1⅛-inch pipe? Standard pipe is made 1-inch, and the next larger is 1¼-inch."

Experience is no doubt an efficient, but wearisome, and oftentimes, a costly teacher, and sometimes from the experiences of others we can learn a great deal. Oftentimes facts stick in our minds and are called to mind when needed, when the bare statements of the principles they illustrate would never be thought of. Sometimes these practical experiences of others will save one a great deal of both time and money, and they are therefore often worth remembering.

When an engine fails to explode its charge, there may be any one of several causes for it, among which is the failure of the igniter to work. This also may be due to several things, and it is usual in testing for the cause to place together the wires from the battery and see if they make a good spark when separated. If they do, we know that the battery is all right. The next step is to learn if we get a spark inside the cylinder. Most engines are provided with a small hole near the igniter points, and in this hole a plug is screwed. The plug may be removed to clean the points or test for a spark. Several years ago an engine was being tested in this way. The engineer called to a man nearby to see if the gas was turned off. The man reported that it was, and the engineer snapped the igniter, at the same time peeping into the hole to see if there was a spark. At that instant there was an explosion in the cylinder, and, of course, the flame blew out through the peephole into the engineer's face. That he was not rendered totally blind was only a miracle. As it was, he was taken to a hospital, where it was two weeks before he could see at all. As for the cause of the explosion, it was never known just what caused it, whether there was in the cylinder a charge of gas, which had not been exploded after the gas was turned off, or whether the person who stated that the gas was turned off was mistaken. Or, possibly, the gas cock was accidentally opened, even if it was closed at the time the gas was reported as shut off. Since the first case of this kind that came to my attention I have heard of several others, although none resulted so seriously.

In making this test on the igniter, it is well to bear in mind the old saying, "If you wish a thing done well, do it yourself." First see that the supply of gas or gasoline is shut off from the engine. Then turn the engine over several times and operate the igniter so as to explode any charge which may be in the cylinder. It is also a good idea to turn the engine over once or twice with the valves and cocks open so as to blow out any charge which may be in the cylinder, for the igniter may not work for several times, and then, just at the moment you happen to be looking in for the spark, it may ignite the charge. As a further safeguard, operate the igniter several times before you attempt to look for the spark, and when you do look, keep your face some distance away from the hole and a little to one side, or else use a mirror to reflect the spark. While these may seem to be rather extraordinary precautions, nothing should be overlooked unless one wishes to run the chance of losing both his eyes.

A somewhat similar incident was told to me by an expert from a gasoline engine factory. He had been sent to locate and correct some reported difficulties in an engine. These were soon fixed all right, but the people had been using a self-starter to operate the engine, and found that it was just as easy and a little less trouble, to start it without the self-starter. They therefore asked the expert if he would disconnect the engine and starter.

They were exceedingly busy, and did not wish to be out of the use of the engine any longer than necessary, especially as they had been shut down for several days already. The expert told them that he could easily disconnect it without stopping the engine, and proceeded to do so. There was a pipe leading from the compressed air tank to the engine cylinder. All that was necessary was to disconnect this and put a plug in its place. This could easily be done by throwing out the switch in the battery circuit, when the engine would run without exploding for several revolutions, during which time the pipe could be unscrewed and the plug put in. Then the switch could be thrown in and the engine would begin to explode the charges, not having lost more than two or three impulses, so that it would soon be up to speed again. But again, "If you wish a thing done well, do it yourself." Everything was ready. The expert was at the engine with a pipe wrench, plug, etc. A man stood at the switch, and at the word threw out the circuit. The pipe was unscrewed, and the plug was just going in when the engine fired. The switch had fallen back into contact and completed the circuit. The expert's hands went "chunk" into a bucket of oil that happened to be standing near. A doctor was summoned and dressed the hands, but it was several weeks before they were of much use to their owner.

Sometimes troubles with gas engines occur in a place where the cause is seldom looked for, because the trouble may have come about gradually and seem to be due to other things. For instance, when an engine heats too much there are several things which may be the cause of it, and yet one of them often escapes the mind of the operator. A steam engineer usually uses some kind of boiler compound to prevent deposits in the boiler, but the gas engineer often overlooks the fact that these same deposits may occur in the water-jacket of his engine. In one case an engine was reported as heating a great deal more than it had formerly done. When the expert examined the engine he found the lower portion of the jacket-space practically filled up with mud, lime, etc., which had baked hard. Of course it had taken several years for this to occur, but as a result of it the water did very little good, and the engine became very hot. In another case, while the jacket-space had not become so completely filled up, the space around the inlet pipe had become pretty well clogged up, so that the water supply was choked down and the engine heated too much. These jacket spaces should be thoroughly cleaned out about once a year, depending on the nature of the water used. If a tank is used, and the same water circulates through the engine over and over, a boiler compound may be used, or rain water instead of water containing lime and other substances which will deposit. This will prevent the trouble to a large extent.

Sometimes the cause of trouble seems to be rather ludicrous when the explanation is known. When large engines are placed in office buildings it is usual to draw air from outdoors through a pipe instead of from the engine room, as the sound of the suction is then reduced and is not annoying. In one case an engine was so arranged, and the end of the air pipe was just outside the building about ten feet from the ground. Some street urchin happened to hear the noise of the air being drawn in and began to throw his cap up towards the end of the pipe, and was amusing himself by seeing the cap suddenly diverted from its course by the air going into the pipe. But once the cap went too near the pipe and was sucked into it, and of course shut off practically all of the air supply, causing the engine to stop. If the boy had not wanted his cap back, the engineer might have hunted a long time before he discovered the cause of the trouble. But caps are not to be thrown away by street Arabs, and so he went into the building to inquire as to how he could get his cap back. This at once made plain the cause of the engine stopping. After trying in vain to blow the cap out by exploding a charge in the engine and holding the air valve open, the pipe was finally taken down, and the cause of the trouble restored to its owner. Since then I have noticed a wire screen is placed over the end of this pipe.

Frequently we are inclined to laugh at the mistakes of others, and say that if that particular trouble happened to our engine we would not be long in finding it. But this is not always a safe position to take, as the following incident will show: A gasoline engine salesman went to see one of his engines, which was reported by the owner to be giving continual trouble. He found that the real cause was that the man who was employed as engineer did not seem to be able to understand the engine at all, and as a result it easily got out of adjustment, and so on. After making some slight adjustments and cleaning up the engine, the salesman proceeded to give the engineer some instructions, in the presence of the owner. He illustrated trivial causes of trouble by relating an experience he had had a few days before, when he went to find what was the matter with another engine. He found that the engineer, in wiping up the engine, had inadvertently allowed a string of waste to get fastened into the gasoline feed, and it had lodged in such a position that it practically cut off the supply of gasoline.

When the waste was removed, the engine started off at once with no further trouble. The engineer to whom the incident was being related, said, "Well, I'm not that dumb, anyway. I'll bet I'd have found it." Soon after he went out of the engine room and the salesman placed a piece of waste in the feed just as he described. When the engineer returned the engine was evidently in trouble, and his face seemed to say, "I told you so. You think the whole trouble is with me, but I know it is the engine." The salesman refused to look for the cause of the trouble, as he said he wanted to see how the engineer went about looking for the cause of trouble. After some fifteen or twenty minutes of vain endeavor, the engineer finally gave up. When the salesman went up to the engine and picked out the waste it of course made the engineer angry, as he thought a trick had been played on him. Nevertheless it showed that he was unable to locate even the slightest trouble with the engine.

The greatest trouble with engineers seems to me to be that they do not have any idea as to how the engine works and what its various parts are for. They can start it or stop it, but when trouble comes they are not sufficiently acquainted with the theoretical part of the engine to understand where to look for the trouble. Many of them will see that the spark is all right, but forget to see if the engine is getting gas or gasoline. Others will see to the fuel supply and forget that if their muffler is choked up the burned gases can not escape. Still others test the engine for compression, but forget that a spark is necessary.

When an engine gives trouble, unless it is very apparent that the cause is in some particular part, it is well for the engineer to have some one method of going over the engine. And even when the trouble seems surely to be in one place, if he is unable to locate it there, let him not forget that his diagnosis may be defective. For instance, a firm recently telegraphed to the manufacturers of their engine, stating that the fuel valve did not seat properly, and asking that a man be sent at once. When he arrived he found that the trouble was not with the fuel valve at all, but that the spring which regulated the mechanism by which the exhaust valve was held open until the proper time, was not tight enough. On tightening this spring the trouble ceased at once. Thus it will often happen that trouble in one place will so affect the working of the engine as to make it appear that the cause of the trouble is in an entirely different place.

These are only a few illustrations of troubles which have occurred in the operation of various engines, none of the troubles having been due to faulty design or workmanship, but to carelessness or ignorance in some form or other. If a steam plant was handled with as little care and intelligence as gas engines often are, the list of casualties from boiler explosions, etc., would soon be so large as to drive the steam engine out of existence. The operation of a gas engine, however, is dependent on principles which, if not followed out, seldom result in more than unsatisfactory work or a complete shutting down of the engine. Sometimes, however, a gas engine is handled in just such a way as to cause almost as disastrous results as a steam boiler explosion. If the engineer, in addition to the practical knowledge gained by handling the engine, will add some theory to his knowledge, so as to know the why of this or that operation, it will enable him to locate the cause of trouble much more readily, as well as in a large measure to prevent trouble.

VII.

ILLUSTRATED TROUBLES.

It is a pretty safe statement to make that there is no piece of machinery which does not at some time or other give some trouble. The tendency of the times is to produce machinery as nearly automatic as possible, in order that the cost of attendance may be reduced, not only by permitting of the employment of less skilled laborers, but also by enabling the laborer to devote his time to as many different machines as possible. For instance, there are the automatic screw machines, several of which may be operated by one comparatively unskilled workman. At first thought this may seem to work to the disadvantage of the skilled man, for he is no longer needed to attend the machines, since cheaper labor has replaced him. But who is to build these screw machines? Does not their manufacture require the labor of even more skilled men than formerly attended the old machines? And so we find that the tendency toward automatic machinery, while replacing some skilled workmen gives employment in the manufacture of the machines to these same and other equally skilled men. And as there is no machine which at some time or other will not get out of adjustment or wear or possibly break some part, men are needed to keep a watch on these kinds of troubles and remedy them. And as the gas or gasoline engine is a machine which is, to a very large extent, automatic, it is not to be expected that it will not also occasionally cause trouble. Even the best of our watches, which represent perhaps the most complete automatons of the day, need frequent winding and occasionally must be overhauled and cleaned. And when a watch needs overhauling, the owner usually employs an expert watchmaker. But when his gas engine causes trouble does he employ an expert gas-engine mechanic to repair it? Too frequently he does not, and either attempts to fix it himself or employs a man who knows little of gas engine construction.

In almost every town there are machinists who are ever willing to attempt any job which is brought to them, whether they know anything about it or not. And when they are called upon to locate and remedy troubles with some gas engine they go at it boldly. Perhaps they have worked on some other make of gas engine, although not the particular make in hand, or perhaps they have never seen a gas engine before. Still, as they claim to be, and perhaps are, expert machinists, they at once start to pull the engine to pieces feeling confident that they will be able to put it together again. But when they attempt to do so, more than likely some part is out of time, leaving the engine in worse shape than when they got hold of it. Now, I do not mean to be understood as saying that an expert machinist, or perhaps even one who does not call himself an expert, can not locate the trouble with a gas engine. I do know, however, from actual experience, that many such machinists when called upon to do such work apparently have no idea of what they are attempting and frequently do more harm than good. Some judgement is required in such cases and the man who dismantles an engine without knowing what he is doing is likely to end up in a muss. In the gas engine factories only the best of mechanics are employed in assembling the engines.

I have in mind a case in the South where the owners of an engine had some trouble in running it on gasoline, although they could run it on gas all right. From their reports there was evidently nothing radically wrong with the engine, since it ran all right on gas, and the trouble no doubt was in the installation of the gasoline system. They employed a local machinist who took the engine to pieces and when he got it together again it was in worse shape than ever. This machinist claimed that it was a practical impossibility for the engine to be run on gasoline. Inasmuch as the engine had been run on gasoline before leaving the factory his statements were manifestly untrue.

Some of the machinists called upon to do this kind of work evidently know nothing of the first principles of gas engine theory. For instance, a machine shop was called upon several years ago to locate a trouble with a gas engine. They had done a great deal of work on steam engines, as well as other work, but evidently they knew little of gas engines, as was evidenced by a letter of inquiry to the manufacturers of the engine, asking "whether or not it was necessary to use both the tube and the electric igniter at the same time." If a gas engine were animate (as they sometimes almost seem to be) what protests it would make when placed in such hands as these! I have also known of cases where a local machinist, thinking that the engine was igniting too late, would set the ignition ahead so that it was too early, and later on, a broken crankshaft was the result.

Uninformed as some machinists seem to be on these questions, one would think that they would devote some attention to the study of the theory and construction of gas engines. One engine owner recently wrote to the manufacturers of his machine, stating that the machine gave good satisfaction, but that like all other machinery it occasionally needed overhauling, and his engineer, who was the janitor of the building, was not competent to do this work. He stated that out of several local machinists he had employed none seemed to have the slightest practical knowledge of a gas engine and he appealed to the manufacturers to write to the various machinists in his town in an endeavor to persuade them to give the subject some study. This condition of affairs is not an uncommon one in many places.

On the other hand, when the gas engine owner or engineer attempts to fix his engine he sometimes does as foolish things as any machinist possibly could do. And the devices to which he sometimes resorts are often less excusable on his part than they would be on the part of even a machinist, since the man who has run an engine for several years ought to know better.

One man had an engine for some time and took the piston out for some purpose or other. Either through ignorance of the consequences, or through inadvertence, he replaced the piston in the cylinder top side down. As the piston end of the connecting rod was lubricated by oil which flowed from the cylinder lubricator on to the top of the piston and through a hole in the piston down to the piston pin, the turning of the piston upside down resulted in no oil reaching the pin. The man then sold the engine to other parties, and of course they had trouble from the very start. They complained of the piston pin heating and sticking, and asked if there ought not to be an oiler located on it, etc. It was finally suggested to them that perhaps the piston had been put in wrong by someone who had taken it out. This led to the discovery of what was the cause of the trouble and since turning the piston over to its proper position they have had no trouble.

In the second chapter of this volume was discussed the effect of cold weather on starting an engine. It was explained that in order to allow for the extra condensation of the priming charge by the cold walls of the cylinder a larger amount of gasoline must be used for priming. This is a simple thing, and yet it seldom is observed by a very large proportion of gas engine users. One man was accustomed in cold weather to wrap hot blankets around the outside of his engine cylinder in an endeavor to heat the cylinder enough to enable him to start the engine. How much simpler it would have been to have used a little larger sized priming charge.

In another case a man had been running his engine for several years, and he got the idea that the cylinder was worn rough, as no doubt it was. His method of overcoming the trouble, however, was certainly unique. He mixed up a quantity of fine sand with heavy machinery oil and put the mixture in the cylinder. Then he started the engine and let it run a while with the oil and sand in the bottom of the cylinder. However, as he himself reported, this did not seem to smooth it any. In fact, it added to the roughness so much that the cylinder had to be rebored and a new piston put in, entailing considerable expense to him.

In a western city there recently occurred an accident which, while not the fault of the owner of the engine, illustrates the complex conditions under which gasoline engines sometimes operate. The oil man who filled the gasoline tank poured a quantity of turpentine instead of gasoline into the tank which was partially empty. But the engine continued to run on this mixture of gasoline and turpentine.

The gas engine battery is, perhaps, one of the parts of the engine equipment which receives much complaint from the owner on account of the cost of renewals. Much time and money has been spent in trying to produce an ideal battery, but frequently batteries are abused so that they do not give even average satisfaction. In some cases call bells are attached to the engine circuit. This soon runs the battery down, and then the battery is blamed instead of the bells. A battery for call bells can be purchased at a low price compared with the cost of the expensive gas engine battery, so that it would seem cheaper to buy a separate battery for the bells.

Another cause of trouble with engines is the use of poorly filtered oil, especially on the crank pin. Oil at this point must be perfectly free from grit or dirt of any kind, and while filtered oil may be used at other points it is very poor policy to use it on the crank pin. Engines are often reported as heating the crank pin, and all suggestions as to what to do seem to be of no avail. When an expert is sent he discovers that filtered oil is being used, which is the sole cause of the trouble. It must be borne in mind that when the crank pin once begins to heat, it is almost impossible to keep it cool, and no chances should be taken with filtered oil where it may save a few cents, but cost many dollars.

These instances illustrate a few of the causes of trouble with gas and gasoline engines. The ability of the gas engine operator to keep his engine in proper adjustment is something which is much to be desired. And if, in addition to this, he can make such repairs as may be necessary from time to time, he is that much more valuable. But not all men have this ability or the skill to acquire it. In such cases care should be taken as to what is done to the engine and who is employed to do it. Because a man calls himself a machinist is no reason that he is competent to overhaul either a steam or a gas engine, and many dollars may be saved by employing a competent man, even though at two or three times the first expense of an inexperienced man, who may do the work all right, or who may utterly ruin the engine.

VIII.

LUBRICATION.

If one were to ask a great many gas-engine salesman what in their opinion was the one thing most characteristic of gas engines which had caused them to become so rapidly adopted as a source of power, the probable answer would be, "The fact that gas and gasoline engines require so little attention." This is apt to be a stumbling-block for the person who buys an engine without having had previous experience or knowledge of such engines. It is being continually impressed on his mind, both by the salesman and the catalogues he receives, that the gas engine requires "no attention whatever." A few of the salesmen who are not less zealous than the others to secure the order, but who are looking forward to the future, may state in an indefinite way that, while gas engines need some attention, the time involved does not really amount to much. The result is that the inexperienced purchaser often is sorely disappointed. He has been under the impression that all that was necessary was to start the engine, after filling the oil-cups, and then let it alone until he wishes to shut it down.

And yet not all this misunderstanding is the fault of the salesman or the manufacturer. In the first place, one should remember that there is no machine which will run indefinitely without needing some attention, and the better and more intelligently the attention is given it, the better the results are likely to be. And if the simplest form of machines require attention occasionally, how can we expect a gas engine (which, of necessity, must be complicated in comparison to a great many kinds of machines) to run without attention? And yet it is undoubtedly true that many engines do run without being cared for at all. The result, however, is that they do not last more than a year or two at best, and then they must be replaced.

If there is one thing that is necessary for the successful operation of a gas engine it is oil. While many gas engine operators seem to recognize this, they fail to bear in mind that oil of a proper quality is needed, and that it is needed in certain places and not needed in others. The operator is apt to become careless and let oil get all over the engine and catch and hold dirt and this gives the engine a very unpleasant appearance, if nothing else. But there are a number of engines which have parts where oil is not intended to go and if it gets there trouble results. Further, oil will get in around working parts and after getting gummed up with dirt, will stick the parts and cause them to operate slowly and stiffly, so that they get out of time. It is a good plan to put some gasoline in a squirt can and squirt some of it on to such parts every week or so. This cleans off the gummy oil and dirt, and after letting the engine run a while with the gasoline, oil can be put on such parts as need it.

The engineer should not fail to wipe his engine off at least once a day. As one writer says, he had better wipe up the engine after shutting down in the evening, for he may not have time to do it in the morning. Then, too, in this way the oil is not allowed to remain on the paint, etc., over night. The writer knows of at least one engine which is cleaned up both at noon and at night, as soon as it is shut down. Although the engine has been in use over a year and a half, the paint is bright and fresh as ever. This may not appear to be of any particular advantage, but if the owner tried to sell his engine secondhand, its appearance would be worth much more than what it has cost him to keep it clean.

The lubrication of the cylinder, however, is one point which many gas engine users seem to attend to with the utmost care, and yet with dire results. Many operators realize that the oiling at this point is a matter of great importance, and they therefore proceed to get the best steam engine cylinder oil at the very highest price. Now, while their intentions are good, their deeds are not. Steam engine cylinder oil is intended to lubricate the cylinder under conditions which are very different from those under which oil in the gas-engine cylinder must operate. In the steam engine there is more or less moisture, and the temperature is fairly high. But in a gas engine, especially after it has been running for several hours, the heat is exceedingly dry and intense, much more so than in a steam engine. The gas engine cylinder oil must, therefore, be able to withstand a very high temperature, and lubricate under very dry conditions. A good grade of gas-engine cylinder oil which has a high flashing-point can be secured for less money than the best steam engine cylinder oil, and answers the purpose better. Any gas-engine manufacturer can furnish such an oil or direct inquiries where to secure it.

But a supply of the proper kind of oil is not all that is necessary. It must be properly applied or fed to the cylinder. It is usual for engines to be supplied with lubricators which hold enough oil for a run of about ten or twelve hours, and in such cases the feed can be set so that one cupful will last about that length of time. Too little oil, of course, causes the piston and cylinder to become dry, and if the lack of oil is continued they will begin to cut and heat. If this condition still continues, the piston may expand so as to stick in the cylinder. I have known of several instances where an engineer forgot to open his lubricator on starting the engine and did not notice it until the engine stopped from the piston sticking in the cylinder. This, of course, cuts the cylinder up badly, and soon necessitates reboring of the cylinder and fitting a new piston.

On the other hand, it is more usual to meet cases where too much cylinder oil is supplied, rather than too little. In their endeavor to avoid the one, many engineers fall into the other habit. The result is not so disastrous to the engine itself as it is to the successful operation of it. If too much oil is fed, the surplus over that which is required for lubrication is forced back into the combustion-space. Here it is partly burned up by the intense heat and flame, and part of it is blown out with the exhaust gases. That which remains becomes gummy and deposits in numerous parts of the cylinder. It falls on the igniter points and prevents a proper spark. It collects around the piston rings and sticks them fast in their grooves, so that they fail to spring out and hold the compression. The oil which is thrown out with the exhaust clogs up the auxiliary exhaust ports, if there are any. I have known these ports to be clogged so completely that a casual examination of the inside of the cylinder failed to show where they were, and it was only by taking a hammer and chisel that they could be found and cleaned out. The burned oil which passes out through the exhaust-valve sticks on the valve stem and seat and causes the valve to work slowly and perhaps not seat entirely. This means frequent regrinding and cleaning of the valve. Then, too, the exhaust-pipe becomes partially clogged up with the grease. The muffler plates also become clogged up with the dirt which is thrown out, and so completely does this occur that it almost prevents the escape of the gases. All these things cause a heavy back pressure in the cylinder and decrease the power developed. In some cases the back pressure of burned gases is so great that the gases contaminate incoming charges to such an extent that they fail to ignite, and the engine will not run at all.

In such cases as these the engine itself, the exhaust-pipe and the muffler must be taken apart and thoroughly cleaned. The muffler plates can be separated and placed into a wood fire to burn off the grease and dirt. The piston rings, exhaust valve, valve stem and other parts can be loosened and cleaned with gasoline or kerosene, which will remove the dirt.

One way in which to tell whether or not the engine is getting too much lubricating oil is to watch the color of the exhaust. This should be practically free from smoke, which always indicates imperfect combustion in some form or other. And as there are only two things to burn in the cylinder, the fuel and the lubricating oil, a smoky exhaust indicates improper conditions of fuel or oil adjustment. The exhaust from an engine which is properly adjusted is nearly colorless. Sometimes it has a faint blue haze. Therefore, when you have a smoky exhaust you can know that it is due to one or the other, or both, of these causes.

When caused by a wrong adjustment of the fuel, it may be remedied by cutting off a portion of the supply of gas or gasoline, so as to give the engine only enough fuel to make perfect combustion. If this does not overcome the smoke, try reducing the feed of lubricating oil. The smoke may continue for several days, however, as there may be considerable grease and oil in the exhaust passages, which it will take several days to burn out.

It is well to use the cylinder oil on any parts of the engine which come in close contact with the heat of the explosions, say such parts as a moving electrode in an electric igniter. This oil will stand the heat and lubricate the parts much better than other oils which burn and gum the parts up. Such parts of an engine should be oiled with gasoline every few days, so as to clean them out well and not allow any burned oil to accumulate. After allowing them to operate a short time with the gasoline they can be oiled with the cylinder oil.

The crank-pin and the piston-pin of a gas engine are also points where good oil is necessary. It is not uncommon to use a grease on the crank-pin, and many users claim that it is better to do so than to use oil. If grease is used, care must be taken to see that there is no dirt in the grease when putting it into the cup. Sometimes there will be lumps of tallow or foreign articles in the grease and these will stop up the tube from the cup and prevent the pin from getting any lubricant.

I have known of cases where engineers had difficulty in keeping the crank-pin cool, and would attempt to use both a grease cup and an oiler on the plan that if one failed the other would not. This plan generally does not operate successfully, as the grease gets into the oil-tube from the oiler and clogs it, so that no oil reaches the pin, and the engine runs the same as though it had only the grease cup.

For the main bearings of the engine, as well as other and less important parts, a good grade of machinery oil may be used. One thing must be borne in mind in lubricating any part of the engine, and that is to use oil which is free from dirt or grit. Filtered oil is sometimes used, and if it is perfectly free from foreign substances it may do no harm, but improperly filtered oil has caused a great deal of trouble to gas engine users, especially when it is applied to the crank-pin. The engineer who once gets his crank-pin to heating will, when he gets another engine, know the value of preventing the crank-pin from heating the first time.

The proper oiling of the engine is one of the most important things in its care. Failure to do this properly may result in an expense of many dollars for repairs and will sooner or later make a new engine necessary. No engine will run without oil being properly applied, and if attention is given to this work the operator will be saved much care and time. Some engines undoubtedly do require more time on the part of the engineer than others, but if the lubrication of the engine is properly attended to the work of caring for the engine will be largely reduced.

IX.

CONDITION OF ENGINE INDICATED BY ITS NOISES.

Did you ever stop to think of how much you can tell about the condition of a gas engine by the sound it is making? It is said that the expert flour miller has his ears so trained from years of practice that as he makes his regular trips about the mill he notices almost unconsciously whether the various machines are running right by the noise they make and that if any particular machine happens to be running out of adjustment in some way, he notices it at once by the unusual sound it makes and is thus able to make any necessary adjustment before serious injury has been done to the machine or the product it is handling. Of course, this ability results only from continual training and practice, and is acquired gradually, but when once thoroughly secured is of unlimited value to its possessor.

The gas-engine operator should try to train his ears in this same way, for by so doing he will undoubtedly be able to save serious damage to the engine by anticipating the breaking of some part, and the consequent serious damage to the engine. Not only this, but by training his ear to gauge the proper running noise of the engine he will be able to secure at all times the full power of the engine and at a minimum fuel consumption.

It is sometimes amusing to see the engine operator, when an expert arrives from the factory in response to calls for assistance to straighten out difficulties with an engine. The expert can often tell merely by the noise the engine is making just where the trouble is, and the engineer who has been *looking* all over the engine and never paying any attention to what he might *hear,* is surprised that the trouble has been located so quickly, and he wonders if the expert merely happened to hit the right thing the first time, or how the trick was done. He never dreams that the ear may tell many things about a gas engine.

For instance, in the case of a hit-and-miss engine, one not infrequently hears one of these engines exhaust with a bang, bang, bang, for ten or fifteen successive times and then cut out one or perhaps two and then exhaust again perhaps fifteen or twenty times. If the explosions have the quick, sharp sound showing that the charges have been of the proper mixture of gas, or gasoline and air, and have been ignited under a strong compression, we can tell at once that the engine is pulling almost its utmost capacity and is therefore likely to get very hot, possibly causing premature explosions, and that its general running may not be satisfactory for the reason that it is operating under too great a load. Although the efficiency of the engine may be greater at that condition of full load there is no doubt but what the continual strain of the engine will shorten its period of usefulness as well as render it necessary to watch continually the engine, to keep it in proper condition.

For if but a single charge fails to ignite, the load will pull the engine down and stop it before it has a chance to recover itself. And if any part wears a little so as to interfere with the proper timing of the other parts, the engine will not pull its load. The water in the cylinder jacket will get exceedingly hot, and if too small a quantity of water is used with a gravity system of circulation, the water may turn to steam and the engine piston begin to expand and stick in the cylinder. This condition of things does actually exist in many places, owing either to having failed to get an engine of sufficient size, or else to having added other machinery which has overtaxed the capacity of the engine. Unless absolutely unavoidable, an engine should not be run under conditions where it can not cut out one charge in at least every ten or a dozen. This gives the engine an opportunity to recover itself if by any chance a charge should fail to explode. It also allows the engine to run a little cooler in case a small amount of water is used for cooling purposes. And the strain on the engine generally is by no means as great, so that its life is considerably prolonged and the increased fuel consumption is so slight as to be hardly noticeable.

Again, how many of us have heard an engine exhaust normally for several times, then miss one or two, and then follow with a terrific explosion, which seemed to tear the whole place up? The writer recently saw a letter from a man whose engine was doing this very thing and he asked whether the engine was likely "to do itself or anyone around it any harm." The man who does not know the cause of this condition is terrified by fear that the engine will do considerable damage to life and property. As a matter of fact this is usually one of the easiest difficulties about a gas engine to overcome. The remedy is in either one or both of two places. The trouble is caused by the fact that one or more charges are not ignited in the cylinder, but are exhausted into the exhaust pipe unexploded. The exhaust flame from the next succeeding charge which is ignited fires the live charge in the exhaust pipe, causing the terrific explosion which is so startling to the average person who does not know its cause. The only damage that is done, however, is sometimes to crack an exhaust pot, break the muffler plates, or blow down a few bricks if the end of the exhaust pipe has been carried into a chimney flue instead of clear through it to the top. The exhaust pipe is strong enough to withstand these explosions so that the danger of injury to property or life is very, very small indeed. One of the causes of these explosions is that for some reason or other the igniter does not work properly. The battery may be weak and give a spark only occasionally, or may give a spark which is so weak that it does not always ignite the charges. Or the mechanism of the igniter may be a little out of adjustment, so that the igniter points do not always come into contact, or the points may be partially corroded and insulated. If a tube igniter is used the burner flame may flicker this way and that and not keep the tube at the proper heat at all times. In other words, if, for any reason, the igniting mechanism is out of adjustment or weak, so that every charge is not ignited in the cylinder, these pipe explosions will result.

The other cause of this condition is partially starving the engine; *i. e.,* giving it too little fuel for each individual charge. As has been explained before in the previous chapters, if a mixture of gas or gasoline vapor has too small an amount of gas or gasoline as compared with the air, it makes a very weak mixture and after a certain proportion is reached the mixture will not be ignited by the electric spark or other igniting mechanism. Accordingly the charge is exhausted unexploded, but a portion of it remains in the cylinder, instead of burned gases or fresh air remaining in the combustion space as is the case immediately after a charge has been exploded. Perhaps two or three of these charges are then exhausted unexploded and finally that portion remaining in the cylinder enriches the new charge to such an extent that it is possible for ignition to occur. When this charge is exhausted, the flame ignites the live charges in the exhaust pipe and the pipe explosion results. As the flame from the exploded charge is much larger and hotter than the electric spark or the hot tube, it ignites the charges in the pipe, whereas they were not ignited by the smaller flame or spark in the cylinder. When the gasoline engine operator once understands these causes of pipe explosions, his ears always tell him when it arises and he at once investigates the igniter and device for regulating the supply of fuel, and finds the cause of the trouble, instead of being scared out of his wits and not doing anything. Using his brains in conjunction with his ears thus enables him to adjust his engine quickly, and thereby not only add to the life of the engine, but prevent it from giving unsatisfactory service, as well as from using or wasting an excessive amount of fuel.

Sometimes hit-and-miss engines will fire once, then cut out six or eight charges, fire again and cut out six or eight, and so on. Investigation may show that the engine is being run at a very high speed and is, of course, carrying a very light load. If this load is the maximum that the engine is called upon to carry, it will often be found better to reduce the speed, which results in less wear and tear on the engine. If at any future time more load is added the speed can then be increased.

One often hears an engine making an exhaust which sounds like the last coughing of a dying dog. That is, it sounds as though the explosion had been very weak and did not give a strong, sharp, quick "bark" which a proper mixture gives. This may be due to wrong fuel adjustment, and while it does no harm to the engine it is the result of an improper mixture of gas or gasoline and air and therefore means that the consumption of fuel will be high for the amount of power developed. Of course, the muffling of the exhaust has much to do with the sound resulting, but when the exhaust is free and in most cases even where it is muffled, much can be told of whether the engine is working under proper conditions by the noise resulting.

The noise or clicks made by the moving parts of an engine are also indicators in many cases to the ear of the practiced engineer, of whether the engine is in proper adjustment. Pounding in the engine is a thing which indicates, under ordinary conditions, to the operator that there is something out of adjustment. Perhaps the boxes on one or both ends of the connecting rod need taking up. This, of course, should be done properly as soon as it is required. In many cases an engineer will look for a long time trying to locate a knock in an engine cylinder or the rod boxes, and will eventually find that it is due to the key in a flywheel being loose. The noise from a loose key is often such that it sounds exactly as though it was made within the cylinder and due to a loose piston. Of course, when the piston is too loose and causes a knock, about the only remedy is to fit a new piston to the cylinder. If the looseness is the result of long-continued wear the cylinder will probably have to be rebored before it can be put into a fit conditon to receive a new piston. If the knock is caused by a loose key in the flywheel, the wheel should be tightened at once. The writer once knew of a case where an engine was reported to be pounding and the parties said that they could not locate it. It was finally found by an engine expert to be in a loose flywheel. Why the wheel had not come off seemed almost a miracle for the keyway was literally chewed by the key until it was nearly double its original width. The source of the trouble was located in the igniter which had been allowed to get out of adjustment and operate too early. This caused the engine to fire against itself, but the momentum of the flywheels carried the engine on although there was a terrific strain on the flywheel hub and the crankshaft. In fact, it was a wonder that the crankshaft had not broken from the strain put upon it. This particular case was an instance of where an engineer had failed to use his eyes, ears, or brains. He, of course, had continual trouble with the engine, and, of course, thought the engine was to blame.

I recently learned of a prospective purchaser of a gas engine who had called at an elevator where a gas engine was in use. He made inquiries as to how they liked their engine and was told that no ordinary man ought ever to tackle any kind of a gas engine; that they required too much specialized knowledge for anyone of ordinary intelligence to be able to run one successfully. If these people should happen to see some men, whom they would be apt to put in the class of men who have the very least amount of technical or common education or intelligence, and would see this class of men successfully taking care of gas engines, they would be obliged to admit that either their own intelligence was exceptionally poor in quality or else that they were mistaken in their views. It is an undeniable fact that there are many men absolutely devoid of what is usually called intelligence, and yet who are able to operate gas engines without trouble. As one southerner said: "There is an old negro near here who never has a bit of trouble with his engine and he hasn't any brains at all, yet he gets along all right." We must therefore admit that technical or specialized intelligence is not always necessary. It undoubtedly is necessary with some of the more complicated engines, and yet a good quality of judgment and common sense is more important in the successful operation of a gas engine than any other one thing. Without this the engineer is bound to have trouble, no matter how technical his education may be. But when, to this trait of good common sense and judgment is added some technical knowledge of the principles of operation of a gas engine, the operator becomes all the more capable of getting the very best results from his engine.

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